A TPC for Measuring High Multiplicity Events at RHIC

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The Relativistic Heavy Ion Collider (RHIC) ran for the first time in the summer of 2000. We gathered data for 2 months with Au beams circulating at 130 A GeV with approximately 10% of the machine's design luminosity. Although the luminosity was low, the multiplicity per event was high. We observed multiplicities ranging from 1 or 2 in ultra peripheral events to 3000 tracks per event in central collisions. I will report on the performance of the STAR TPC in this demanding environment.

STAR contains a large, cylindrical, Time Projection Chamber (TPC) as its primary detector system. The TPC has full azimuthal coverage and has an active volume that extends from –1.5 to +1.5 units of pseudo-rapidity. See figure one.

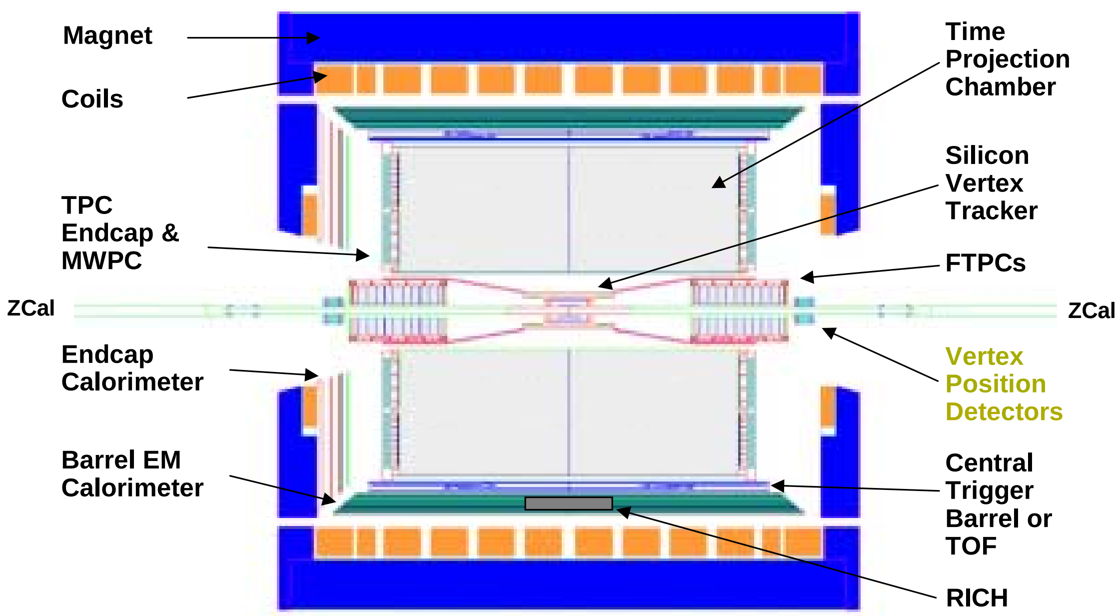

Figure One: The STAR TPC surrounds the interaction region at RHIC. As a particle flies: there will be a silicon vertex tracker close to the interaction region, then the TPC, and finally EM calorimeters all around the outside. Forward TPC's complement the coverage of the main TPC. For the first cycle of operation, only the TPC, the RICH, and the Central Trigger Barrel were installed.

Figure 2 shows a schematic view of the TPC. The cathode is at the center of the tracking volume and it establishes the overall electric field of 148 V/cm inside the TPC. Electrons from primary tracks in the TPC drift towards the pad planes on both ends. Figure 3 shows that the outer part of each pad plane sector is densely populated with large pads to establish good dE/dx coverage. The inner part of each sector is more sparsely populated with smaller pads to enhance the two-track resolution between close pairs of tracks. Each sector contains 5690 pads for a total of approximately 137,000 pixels in the whole TPC and 50 million volume elements (voxels) to be readout into time buckets.

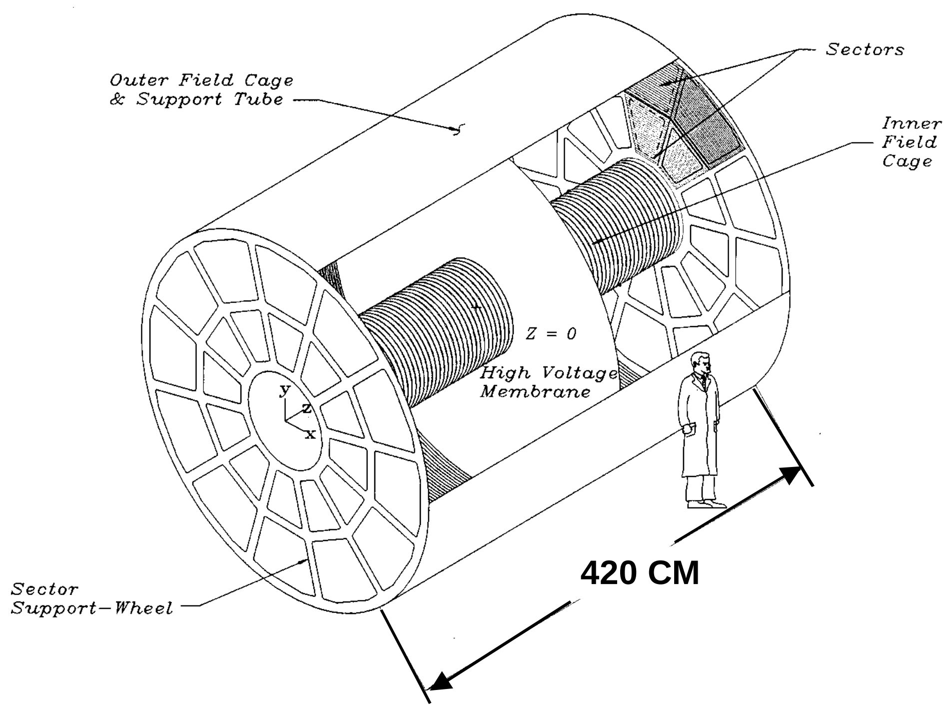

Figure 2: The TPC is 4.2 meters long and 4 meters in diameter. Twenty four pad plane read-out sectors are distributed across the two ends of the TPC.

The wire planes above the pads include a gating grid, a ground plane, and the anodes. The anode wires are spaced 4 mm above the pad plane in the outer portion of each sector and 2 mm above the pad plane in the inner sectors. The anode wire planes are wound without the use of field wires between the anode wires and each anode wire is independently terminated to limit the cross talk between channels. Wire to wire cross talk was observed to be less than 6%.

We chose to run the anodes at a 20:1 signal to noise ratio. This requires a gas gain of 1100 (1380 V) on the outer sectors and a gain of 3000 (1150 V) on the inner sectors. The higher gain on the inner sectors is required because of the smaller pad size in this region, but overall, these are relatively low gain settings.

This design has turned out to be simple and reliable. By avoiding field shaping wires in the anode plane, we eliminated the small HV gaps at the ends of the wires and thus we reduced the potential for micro-discharge across the epoxy bonds used to hold the wires in place. And the low gain setting means that we could run for decades before there would be a problem with wire aging.

STAR uses an innovative electronics package to amplify the pad plane signals. There are two chips. The first chip is the pre-amplifier, shaper, and buffer. The noise is approximately 1000 electrons RMS. The second chip is a switched capacitor array (SCA) followed by an ADC. Since the SCA is an analog memory, the design allows for programmable timing sequences during the signal processing and thus it is possible to avoid digital noise during the most critical analog operations. This is one of the features that makes it possible to have analog and digital signals on one very compact front end electronics board (FEE).

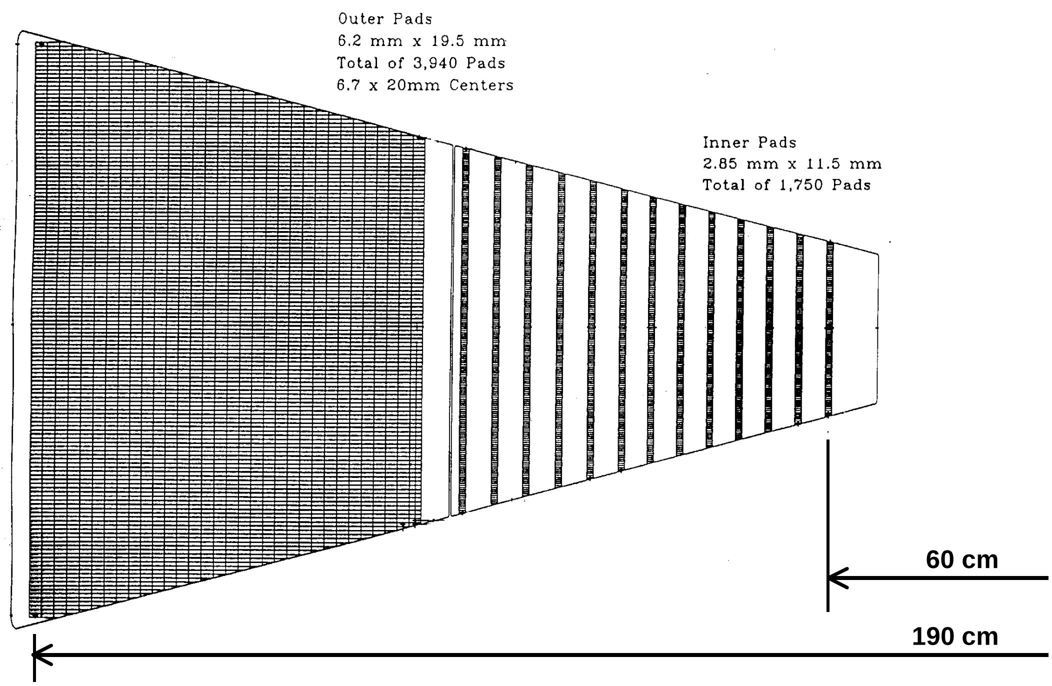

Figure 3: The read-out pad plane is segmented into two sub-regions. The outer region is populated with pads that are 6.2 mm wide by 19.5 mm long and the coverage is complete. The inner region has smaller pads which are optimized for tracking. They are 2.85 mm wide by 11.5 mm long. Their size is set by the diffusion limit of the TPC.

The front end cards deliver ADC values, channel by channel, to a read out board (RDO) and there are 6 RDO board's per sector. The RDO's tag and multiplex the data and feed it down a gigabit optical fiber link to the data acquisition system. The STAR data acquisition system records one central event per second (> 1000 tracks) and up to 30 peripheral events (< 100 tracks) per second. The primary limit on the DAQ rate is the rate to which data can be written to tape (~ 20 MB per second).

The TPC is triggered by an array of plastic scintillator slats all around the perimeter of the TPC and by two small calorimeters at zero degrees. In addition to this hardware trigger, we have a sophisticated online software trigger. In 200 milliseconds, or less, the software trigger will reconstruct all of the tracks in the TPC, find the event vertex in 3 dimensions, and provide dE/dx information for each track. Cuts can then be applied to these parameters in order to select which events are good candidates to save and archive to tape. During the summer of 2000, the luminosity was relatively low and so we only used the vertex selection capabilities of the software trigger.

The performance of the TPC is excellent. One way we have to assess this is to look at the residuals between the fit tracks and the measured TPC space points. The raw residuals are 250 microns, or less. But after correcting for millimeter scale ExB distortions, electrostatic distortions between the inner and outer sectors, and surveyed millimeters scale displacements of the TPC from its ideal position, we are able to calibrate the TPC tracking in a parameter free way to achieve better than 50 micron residuals. See figure four.

In summary, the STAR TPC ran well during its first run. Approximately one-half million physics events were recorded and analyzed during the summer of 2000. We recorded event multiplicities in excess of 3000 tracks per event and we do not see any obvious limitations or complications due to space charge effects. The momentum resolution is better than 2%. The two-track resolution for HBT-pairs of tracks is 2.5 cm and it is 1.5 cm for laser tracks. The single point resolution is 500 μm and the dependence on track crossing angle and dip angle agrees very well with our microscopic simulations. Finally, the dE/dx resolution is excellent. We are able to separate the pion band and the proton band at momenta up to 1.3 GeV/c and the resolution is 7.5 %. And we expect that all of this will improve with further refinements in the software.

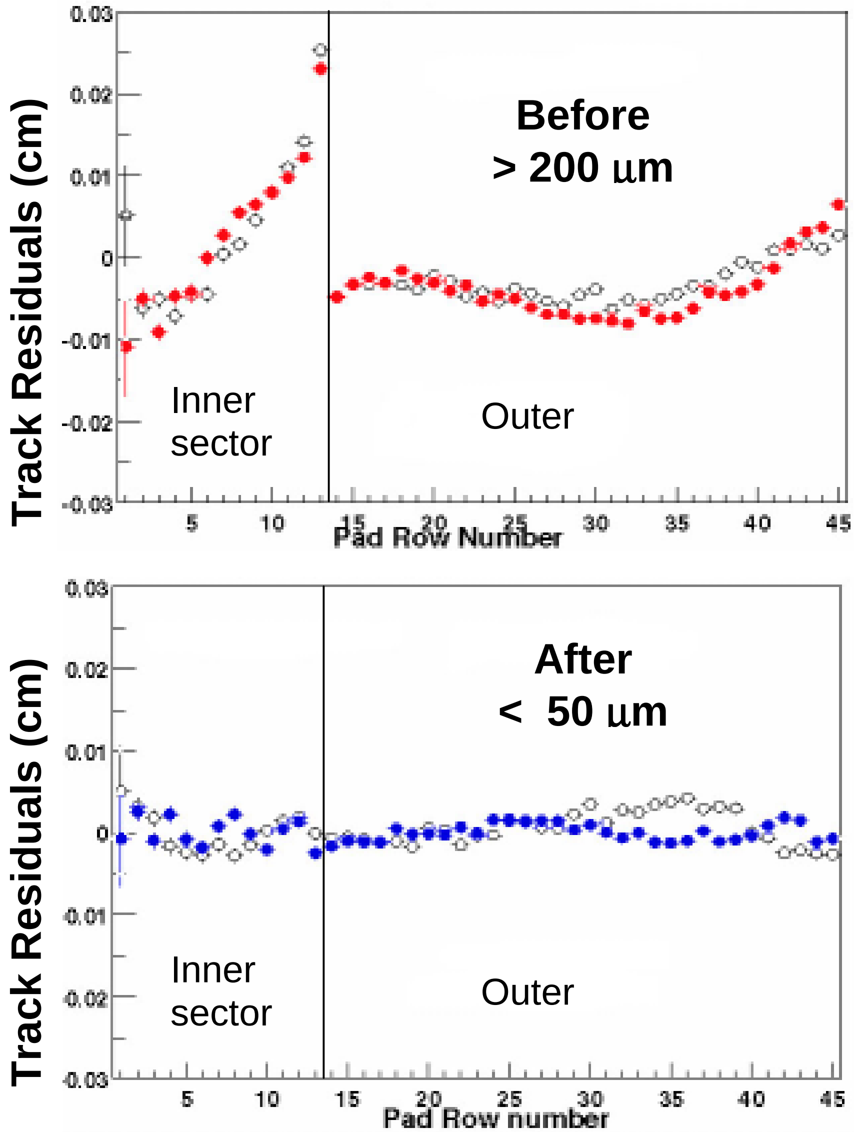

Figure 4: The difference between the fitted track position and the measured TPC hit locations are plotted as residuals versus the sector pad row number. Larger row numbers lie at larger radii. Pad row 13 marks the boundary between the inner sector and the outer sector. We are able to correct for all of these distortions in a parameter free way using surveyed data and measured field maps. The results are as shown in the bottom part of the figure.